



# Research on science and technological entrepreneurship education: What needs to happen next?

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## Abstract

This paper discusses the challenges of technological entrepreneurship education in the current education system and the questions that need to be answered to improve the efficacy and efficiency of technological entrepreneurship education. The nature of technological entrepreneurship requires a diversified set of skills for success; however, the traditional education system focuses on single discipline. Consequently, it is difficult for either engineers and scientists who are lacking managerial skills or management students who are lacking of engineer or science oriented knowledge to be successful. A further concern is that different communities have entirely different perceptions of how entrepreneurship is defined often causing both confusion and disagreement in communications between researchers and educators with each other. The paper considers the existing literature and develops a series of comprehensive questions that still need to be addressed. By answering these questions, the traditional education methods can be transformed to be more appropriate and useful for technological entrepreneurship education.

**Keywords** Entrepreneurship · Education · Pedagogy · Technological entrepreneurship · Entrepreneurial university

**JEL Classification** O310 · A20 · A21 · A22 · A23 · A29

## 1 Introduction

This paper provides insight into the many challenges of Technological Entrepreneurship Education to assist researchers and educators in moving forward with this area of knowledge and education in all its different forms. While pioneering work has been conducted in the United States (Creed et al. 2002; Ramachandran et al. 2002; Standish-Kuon and Rice 2002; Nichols and Armstrong 2003; Weilerstein et al. 2003; McCorquodale and Brown

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2004; Stone et al. 2005; Thursby 2005; Evans et al. 2007) and this has greatly expanded the concept of technological entrepreneurship education (Thursby et al. 2009; Garcia et al. 2010; Herz et al. 2010; Waters 2010; Yock et al. 2011; Bradley et al. 2013; Schillebeeckx et al. 2013; Phan 2014; Addae et al. 2015; Oswald Beiler 2015; Bosman and Fernhaber 2017; Hayter et al. 2017; Huang-Saad et al. 2017), different forms of these activities are now seen as important by a wide range of stakeholder in many jurisdictions around the world (Wang and Wong 2004; Papayannakis et al. 2008; Alshumaimri et al. 2010; Wang and Verzat 2011; Solesvik 2013; Oehler et al. 2015). These challenges can be summarized as: philosophical, structural, and pedagogical. A failure to address all three challenges simultaneously typically leads to disagreement in results due to differences in fundamental definitions and expectations. These challenges are, therefore, a barrier to generalizable theory (the researcher's goal) and agreed upon best pedagogical practices (the educator's goal). By addressing these concerns, it is possible to provide a clearer perspective on what has been considered to date and provide insights into what still needs to be done to provide scientists and engineers with appropriate and effective entrepreneurship education. Such an approach also offers insights into what business/management specialists and students may require for greater success in technological entrepreneurship (Schilling and Klamma 2010; Weaver et al. 2010).

Prior to examining the interaction of the challenges that entrepreneurship education for engineers and scientists involve, it is appropriate to consider why technological entrepreneurship education is increasingly considered to be important. Concerns relating to the cost and value to society of university education have resulted in an expectation that universities play a greater role in the creation of economic value (Wright 2014). This expectation has increasingly led to the discussion of the third mission of universities and the entrepreneurial university concept (Etzkowitz et al. 2000; Philpott et al. 2011; Guerrero and Urbano 2012; Wu and Zhou 2012; Sam and van der Sijde 2014; Trencher et al. 2014; Knockaert et al. 2015; Brown 2016; Calcagnini et al. 2016; Cesaroni and Piccaluga 2016). Furthermore, there has been a recognition from the economic development community that it is easier to retain and benefit from firms that are founded locally, then to attract in and retain firms that have been founded elsewhere (Feldman and Francis 2004; Wennekens et al. 2005; Stam 2007; Wennekens et al. 2010). Consequently, there is increasing interest in using local knowledge and educational infrastructure to increase the number and quality of local start-ups (Shah and Pahnke 2014; Hayter 2015; Miranda et al. 2018; van Stijn et al. 2018). This is especially the case for technology-intensive start-ups as these firms are seen as having: a lower failure rate, a higher propensity to export, greater growth potential and the possibility of higher margins (Åstebro et al. 2012; Carree et al. 2014). While these policy and stakeholder concerns may contribute to the willingness to prioritize resources and attention to entrepreneurship, the student is the only customer that matters in terms of the content and delivery mode of entrepreneurship education. Different student groups have different priorities and knowledge. Consequently, entrepreneurship education may differ greatly within a single institution to suit the needs of different student groups. Having considered the timeliness of better understanding technological entrepreneurship pedagogy, the philosophical challenge is now considered.

## 2 The philosophical challenge

Business, Engineering, and Science differ not only in practitioner activities and educational content, but in their underlying goals (Steiner 1998). The result is that self-selection into one of these three areas typically reflects the presence of a specific type of mindset. Furthermore, socialization within each community reinforces the mindset that is present, appropriate and different for each of business, engineering and science.

The focus of business is the creation of profit. Consequently, individuals who are focused on business seek to identify and extract value from activities that they are associated with. In some situations, the extracted value is the result of creation of new value through innovation and/or entrepreneurship. In other situations, the value either already exists or is created by others. The business-focused individual provides value by identifying how to best extract value from a set of activities. This typically involves determining who is willing and able to pay the greatest amount beyond the cost of providing something. In terms of entrepreneurship education, a focus on maximizing value creation has typically been expressed as activities related to the development of new business ventures. As only some management students are interested in venture creation, entrepreneurship courses are seen as an option that students may select if specifically interested in venture creation (Wang and Wong 2004).

The focus of engineering is the application of science to serve some specific social purpose. Hence, engineers have a strong applied knowledge of science. They see their mission as achieving objectives (eliminate problems/provide benefits) through the appropriate application of scientific principles. As value and profit are not core to the mindset, training or socialization of engineers; venture creation is not a direct goal. However, developing a proficiency for applying engineering skills in a manner that fits better with society's needs and expectations is highly valued. Hence, engineers who have created successful new ventures are seen as exemplars of successfully merging the problem solving aspects of engineering with a specific valuable social purpose. The successful new venture is seen as evidence of the presence of the two desired skillsets: problem solving and fulfilling the needs of society. When members of the engineering profession discuss the importance of entrepreneurship, they often are referring to the skill of recognizing social problems and having the set of abilities that allow one's technical solution to be accepted and appreciated by people that lack the technical understanding of other engineers. While such a skill set is present in engineers that are founders of successful technology-intensive businesses, new venture creation is not something that the engineering profession considers to be core to its mission. Hence an interest in entrepreneurship is often focused on the associated skill set: identification of problems of great importance, social and communication skills, an ability to deal effectively with people who are not technically inclined, flexibility in skill set, and willingness to do what is required to complete a task amongst other organizational skills. These sorts of skills are often referred to as having an entrepreneurial spirit or mindset. Entrepreneurship to the engineer is more likely to involve solving a social problem in which no financial profit is achievable, obtaining management skills or being able to interact well with a wide range of people (different cultures, education and background) as opposed to new venture creation (Arora and Faraone 2003; Aranha et al. 2018). In fact, new venture creation could be seen as an unattractive distraction as venture-creation requires a set of skills that is unrelated to the engineer's daily activities and training. While the identification and encouragement of the segment of engineering students that are entrepreneurially-oriented is advocated (Berglund and Wennberg 2006; Wang and

Verzat 2011; Solesvik 2013; Da Silva et al. 2015; Duval-Couetil et al. 2016; Westhead and Solesvik 2016; Barba-Sánchez and Atienza-Sahuquillo 2018; Yi and Duval-Couetil 2018), many engineering educators consider the entrepreneurial mind-set to be an appropriate part of the core of all engineering programs to be provided to all students (Standish-Kuon and Rice 2002; Galloway et al. 2006; Besterfield-Sacre et al. 2016). On the surface the technical nature of science may suggest that scientists and engineers will be similar, but the pure and applied scientists are in fact quite different.

The focus of scientists (both natural and social) is on developing an understanding of how and why phenomena act in the manner that they do—through the development and testing of theory. Scientists are not tasked with and often unconcerned about how the knowledge they develop can be used to accomplish tasks or solve problems; this is very different from the focus of engineers. Nor are scientists concerned about the identification and capturing of economic value (profit); this differs from business people and managers. Consequently to individuals with a science-orientation, the idea of applying and profiting from theoretical knowledge is seen as abandoning a worthwhile activity to do something mundane and trivial (Kalar and Antoncic 2015); prone to references such as going to the dark-side. The discussion of entrepreneurship education for the natural and social scientists is much less common. In fact, discussion of entrepreneurial activity of any nature is much less frequent when any form of pure science is considered as someone with a purely scientific outlook has no interest in this subject. When activity of an entrepreneurial-nature occurs, it is usually a consequence of someone having more than one orientation—this is having two or three orientations simultaneously (i.e. engineering and/or business/management). As a result, incentives for scientists to behave in a more business or entrepreneurial manner are likely to result in the development of skills that assist in being a better scientist; such as: grant writing, grant management and budgeting, intellectual property and development activities that have a dual purpose such as offering potential new avenues of research.

There are fundamental differences between business/management, engineering and science due to a fundamental difference in outlook: value creation and capture versus application of understanding to achieve outcomes versus developing fundamental understanding of how things interrelate. These fundamental differences shape the manner in which business management, engineering, and science define entrepreneurship (Gilmartin et al. 2016). Such a substantial difference in definition contributes to other structural challenges associated with entrepreneurship education occurring outside of its traditional home—schools of business and management.

### 3 The structural challenge

For now, the difference in perception of what constitutes entrepreneurship is put aside, so that the structural challenge can be considered. While there are many positive anecdotes relating to technological entrepreneurship, stories that describe the road to economic success frequently feature serendipity. While success in new venture creation involves the confluence of many positive events; the relevant body of knowledge and challenges to an emerging organization are well understood and documented. The real challenge is not understanding serendipity so it can be encouraged, but ensuring that the existing technological, venture creation and business management knowledge are all present in an organization so that neither technical nor managerial issues undermine the potential for success.

Failure to so equip an organization results in a reliance on serendipity leading to an unnecessarily high number of venture failures and wasted potential.

The overall dilemma is that our education systems focus in depth on a single discipline, while technological entrepreneurship is inherently interdisciplinary (Papayannakis et al. 2008). Consequently, there are no departments in colleges, institutions and universities that are equipped to simultaneously educate in both scientific/technical and business/managerial disciplines. As educational programs are based on departmental structures, there is an absence of appropriate university programs for preparing the full, part time or continuing education student as technological entrepreneurs (Albert et al. 1991). Some programs are attempting to overcome this challenge through cooperation between departments and/or universities (McCorquodale and Brown 2004; Chapman and Skinner 2006; McCarver et al. 2010; Phan 2014) through the use of Interdisciplinary Entrepreneurship Centers and Entrepreneurship Across the Curriculum Initiatives.

As individuals (downstream of the university) and policy makers (upstream of the university) recognize that technological entrepreneurship is a valuable skill-set for both the individual and the location in which the individual lives and works, there is both demand at the level of the user/customer and the government organizations that both regulate and support new and existing programs (Feldman and Francis 2004; Wennekers et al. 2005, 2010; Stam 2007; Algieri et al. 2013). More importantly, there is tremendous student demand for courses and programs that develop entrepreneurial skills. While technological entrepreneurship faces a structural gap—a significant problem—that is gradually being addressed in some institutions (Audretsch 2014; Rasmussen and Wright 2015), the focus of research needs to be on what will support technological entrepreneurship education assuming that the structure of educational institutions does not forbid it from occurring.

#### 4 The pedagogical challenge

Advances in technological entrepreneurship education are being held back by disagreements in definition. To move forward, technological entrepreneurship must be recognized as a multi-dimensional trait. The dimensions under consideration could then be reported when either theoretical research and practical applications are considered. Failure to do so will result in arguments over definition and misunderstandings about what objectives are being pursued in research studies and class room interventions. Depending on the dimension(s) of technological entrepreneurship that is being pursued, the target audience will vary in terms of both mindset, background and training. The target audience will also vary at one extreme nomination or self-selection of individuals and at the other extreme inclusion of all. Moving beyond these fundamentals already raised earlier on in the text, attention can be turned to additional issues of concern.

For technological entrepreneurship to work, the widespread practice of remaining within single discipline silos, must be modified or even completely abandoned. If skill sets in other disciplines are considered, they are often addressed in an elementary manner. Interestingly, basic or even superficial skills in another discipline are a sufficient differentiating factor to improve the perception of the individual in terms of employability. While there is anecdotal evidence of the value of interdisciplinary approaches, the outcomes lack sufficient control and measurement. For example, Harvey Mudd's Engineering graduates are reputed to have high initial and mid-career earnings (Payscale, 2018) due to an interdisciplinary requirement of an engineering major with an arts or social sciences minor.

The challenge of technological entrepreneurship is that the scientists and engineers lack management knowledge and skills and the management specialists lack knowledge and skills in science and engineering. Much discussion and activity has focused on providing engineers and scientists with managerial knowledge and capabilities, such as: leadership (Farr and Brazil 2009), and other soft skills (Johari et al. 2016). This is a departure from the use of a Master in Business Administration to offer much of the content covered in an undergraduate business degree to individuals who may have no prior exposure to management education such as engineers and scientists. However, there is little discussion of how to provide students of business and management with advanced scientific and/or technological knowledge that could support entrepreneurship activity.

While exceptions exist (Levie 2014; Phan 2014), much of the work relating to exposure of science and/or engineering students to management knowledge through course work or experiential activities focuses on the impact of these exercises to increase the intention to participate in entrepreneurial activities (Berglund and Wennberg 2006; Wang and Verzat 2011; Solesvik 2013; Da Silva et al. 2015; Duval-Couetil et al. 2016; Westhead and Solesvik 2016; Barba-Sánchez and Atienza-Sahuquillo 2018; Huang-Saad et al. 2018; Yi and Duval-Couetil 2018). Understanding whether a treatment has an impact on intention is useful, but is only a first step. There are many questions that need to be answered to provide appropriate cross-disciplinary education to encourage and equip individuals to be confident in not only pursuing technological entrepreneurship, whatever definition is used, but improving the students' likelihood of success.

## 5 The research challenge

To date research and development of technological entrepreneurship education has focused around extension and modification of existing practice within a university environment (Galloway and Brown 2002; Mentoor and Friedrich 2007; Farhangmehr et al. 2016). Such an approach is unsurprising as the typical way of addressing a challenge is to consider whether an extension to an existing system can be addressed with or without modification of existing practices. As noted, the interdisciplinary nature of technological entrepreneurship education presents a number of challenges to the university environment. This raises the fundamental question of to what extent existing systems are relevant. To understand whether minor changes are needed to existing systems or a completely different approach to skills acquisition and development is needed; one must be able to recognize to what extent an intervention has been successful. Once successful interventions are achieved, the next step is to determine how to maximize the output for a given unit of input. Technological entrepreneurship education has failed to meet this fundamental requirement as success often focuses on motivation and intentions (Farhangmehr et al. 2016; Barba-Sánchez and Atienza-Sahuquillo 2018; Wilde and Leonard 2018), as researchers we need to develop appropriate measures to understand how educational experiences lead not only to intention, but action that transform opportunity into activities that are sustainable and economically and social beneficial. Different measures are needed to determine if the student is more *entrepreneurial* and can navigate a series of challenges whether one is considering the growth of either an individual or a start-up. Finally, measures should consider the different sorts of goals that may be intended by and motivate the educator. There are a variety of possible intents, including:

- Encourage people to develop a more entrepreneurial personality and outlook,
- Encourage people to be more self-confident,
- Develop soft skills of people,
- Improve ability of people to work with different types of people,
- Improve ability of people to cope with and work in environments with higher levels of uncertainty,
- Encourage people to identify and pursue opportunities,
- Increase the diversity of job opportunities for post graduates (Horta et al. 2016; Hayter et al. 2017),
- Develop opportunities that will provide the entrepreneur with economic self-sufficiency and/or satisfaction,
- Maximize the economic benefit possibly attainable for a geographic area,
- Develop business that are economically and/or environmentally sustainable, and
- Create benefits to the host society.

In the absence of appropriate measures of success, increasing our understanding of entrepreneurship education will be neither effective nor efficient. Having identified gaps in outcome measurement in past research, attention is directed at the basic assumptions of past research.

While much of the education activities has focused on technically-oriented students, one must ask why there is not a greater focus on others:

- To what extent should technological entrepreneurship education be offered for students with a major in management or other areas?
- How and when should academic entrepreneurship be encouraged so that employees of the university—both academic and professional services staff—create economic opportunity in an appropriate manner?
- What is the ethical use of position, knowledge and resources that are available in different degrees to members of the university community? and
- What constitutes a conflict of interest?

Although such questions about the application of entrepreneurship education are fundamental, they mask the even more basic question of *Is university the appropriate time for entrepreneurship education?* Perhaps entrepreneurship education should start much earlier—in primary school—or much later—after an individual has many years of industrial experience (Huang-Saad et al. 2017).

In addition to questions of when research should occur, there is also the question of where it is most appropriate. Reviews (Da Silva et al. 2015; Huang-Saad et al. 2018) indicate that the class room is the frequent place for learning to be an entrepreneur. However experiential activities, interdisciplinary activities and simulations have been found to be more effective for learning than a traditional lecture setting for many skills; perhaps vastly different approaches such as apprenticeships (followed in many skilled trades) is more suitable. Anecdotes given about how investors look for the presence of failed entrepreneurs, as part of a start-up team (Ekanem and Wyer 2007; Hsu et al. 2017; Eklund et al. 2018), suggest that the traditional models of accreditation and training may be inappropriate. Other possible venues for learning include programs and courses that involve: incubators (Lamine et al. 2018), lean methodology (Blank 2013), i-corps like programs (Youtie and Shapira 2017; Semcow and Morrison 2018) and proof of concept centres (Bradley et al. 2013; Maia and Claro 2013; Hayter and Link 2015).



The fundamental questions—definition, location, timing, and mode—in effect ask if the dominant approach to technological entrepreneurship education is misdirected. It is, therefore, apparent that we need to carefully document interventions to understand what is most suitable set of pedagogical practices to achieve each single dimension and the varied combination of dimensions associated with the multi-trait construct entrepreneurship. In doing so, educators will be able to move towards a set of best practices that consider the various definitions, goals and student groups.

While the absence of an underlying theoretical base is recognized as a challenge to technological entrepreneurship both as researchers and educators (Da Silva et al. 2015; Huang-Saad et al. 2018), the challenge is much more basic and fundamental: *why are we interested in entrepreneurship education and what do we hope to achieve?* There are many possible answers to these questions. While the answers may not have a tremendous impact on the body of knowledge required, it does have a tremendous impact on the timing of and nature of the intervention. Hence, we must consider:

- Are we trying to make scientists and/or engineers more reflective about their interaction with the *social world*?
- Are we after economic growth?
- Are we trying to encourage business oriented students into science?
- Are we interested in social entrepreneurship?
- Are we looking for entrepreneurial universities?
- Are we trying to engage new groups in STEM? and
- Are we pursuing either a different goal or combination of goals than listed above?

Once the definition of and goals for entrepreneurship education are identified, an appropriate body-of-knowledge can be stated. For example, if the focus is venture creation then the body of knowledge would include:

- The definition of a business model showing how value is created and extracted;
- How the start-up acquires the needed resources: financial, infrastructure, human and information to grow and navigate the challenges that face a new venture as it grows towards maturity;
- How the organization matures to a sustainable steady-state organization;
- How the mature organization allows itself the flexibility to innovate so that the business does not become obsolete and decline; and
- Recognizing the different motivations of stakeholders at different points in time and how these motivations are in-line/impossible with the survival and development of the firm.

Such a body of knowledge is much wider in scope and longer in duration than a university course; raising the question of whether the delivery of university courses is the most appropriate mode (Arias-Aranda and Bustinza-Sánchez 2009; Barakat et al. 2014).

The next set of questions relate to Who, Where, and When:

- Who are the best targets for entrepreneurship education?
- When should these educational interventions be delivered?
- Where is the best place to deliver these interventions?
- What are the implications of selecting different targets?
- How do we determine who the best targets are?



- How do the where and when variables interact with the?

Having answered questions regarding definitions, goals, body-of-knowledge and targets; the many important operational questions can be considered. These include:

- What is the appropriate timing and order?
- How do the existing systems and incentives need to be restructured?
- How do we bridge/link/intermingle traditionally separate disciplines?
- How does one avoid/minimize the difficulties associated with turf battles (for example: entrepreneurship vs. innovation or business vs. engineering)?
- How much of exactly what do technical specialists need to interact well with the non-technical/less technical members of a technological entrepreneurship team?
- How much knowledge is required for absorptive capacity to exist? and
- How is entrepreneurship and technological entrepreneurship different/similar?

Unfortunately, the lack of systematic consideration has prevented the solid pedagogical and research work conducted to date from having its maximum possible impact. Due to the interdisciplinary nature, number and complexity of these challenges forward movement towards pedagogical best practice and identification of underlying theory is a tremendous challenge. However, it is a challenge worth pursuing.

## 6 Conclusions

To date the university and the course have been considered by many researchers to be the logical level and unit of analysis of technological entrepreneurship education. It is quite possible that the traditional lecture-based courses should be completely replaced by completely different models of learning in the case of technological entrepreneurship education. This has already occurred in some institutions by emphasizing projects and in some cases linking them to final year undergraduate theses. But there is further room for innovation in educational delivery mechanisms. All research programs and interventions aimed at gaining a better understanding of technological entrepreneurship education must clearly state what the intervention goal is, for example: helping students develop the skills needed to be technological entrepreneurs, raising the economic value of scientists through skills diversification, or commercializing university innovation.

Research needs to focus not only on evaluating interventions, but the underlying theoretical relations that lead to entrepreneurship and success as an entrepreneur. Before this can be achieved the definition of entrepreneur will need to be completely addressed to ensure that research sets out to investigate the same phenomena so that results can be compared. From the perspective of the research community, it is desirable for the range of meaning associated to entrepreneurship to be narrow and concise. However, it is apparent that such an outcome is unlikely. It is possible to treat technological entrepreneurship education as a multi-trait construct made up of such traits as: soft skills, intent to form business, business skills, understanding of value creation and attitude and skills related to uncertain environments. There needs to be an inventory of traits so that a comprehensive definition can be offered along with how to measure it. Once this is accomplished research can (and needs to) be conducted to better understand the relative efficacy of different targets, settings and

educational techniques. In order to achieve this, appropriate measures for testing success must be developed along with a clear and complete understanding of what the appropriate body of knowledge on technological entrepreneurship is. With measures and a body of knowledge clearly defined and the goal of interventions clearly stated, it will be possible to test the efficacy and efficiency of interventions. In addition, structural issues such as the optimal order of exposure to information and the most appropriate type of intervention can be determined. There has been sufficient pioneering work in the field of technological entrepreneurship education that the current understanding allows for future research to give careful consideration of what foundations need to be built to support the field's development into a structured mature field of inquiry.

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